UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C., 20460

NOV 21 2017

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM

SUBJECT: Benefits of Neonicotinoid Insecticide Use in the Pre-Bloom and Bloom Periods of Cotton

FROM: Kara Welch, M.S., Entomologist K Welch
Clayton Myers, Ph. D, Entomologist Monisha Kaul for Clayton Myers
Biological Analysis Branch

T J Wyatt, Agricultural Economist TJ Wyatt
Economic Analysis Branch
Biological and Economic Analysis Division (7503P)

THRU: Monisha Kaul, Chief Monisha Kaul
Biological Analysis Branch

Timothy Kiely, Chief
Economic Analysis Branch
Biological and Economic Analysis Division (7503P)

TO: Thomas Harty, Chemical Review Manager (Clothianidin, Thiamethoxam)
Steven Snyderman, Chemical Review Manager (Dinotefuran, Imidacloprid)
Risk Management and Implementation Branch 1

CC: Melissa Grable, Team Leader
Ricardo Jones, Team Leader
Risk Management and Implementation Branch 1

BEAD Product Review Panel Date: 3 May 2017

SUMMARY

The Environmental Protection Agency (EPA) is evaluating and considering whether potential risk mitigation measures are needed to address risk concerns to pollinator health associated with the use of nitroguanidine neonicotinoid insecticides: clothianidin, dinotefuran, imidacloprid, and

ED_006569M_00137204-00001

thiamethoxam. Risks to pollinators are particularly high when these chemicals are applied during the pre-bloom and bloom periods of cotton, that is, from pinhead squaring to bloom and through to harvest. This memorandum outlines the benefits of neonicotinoid use in cotton and the potential impacts if EPA were to consider restricting foliar applications of these active ingredients during these periods to address pollinator risks. While EPA typically releases benefit assessments along with the proposed interim decisions, EPA is releasing draft benefit assessments prior to proposing decisions in anticipation that early information from the public on the benefits of these compounds will be helpful as the Agency develops what, if any, mitigation options might be needed to address risks to bees, as well as risks to other taxa and to human health.

If EPA were to restrict growers from using neonicotinoids on cotton following pinhead squaring through harvest, the Biological and Economic Analysis Division (BEAD) estimates that the annual impact would result in increased insecticide costs of $5.70 per acre treated with neonicotinoids. This represents an impact of approximately 2.3 percent of an average cotton growers net operating revenue. The average increase in grower costs would vary from $2.80 per acre in the Southeast to $7.10 per acre in the Mid-South cotton region encompassing Arkansas, Louisiana, Mississippi, Missouri, and Tennessee. There are regional differences in the costs and returns to cotton. Impacts vary from less than one percent of net operating revenue in the West to almost three percent of net operating revenue, in the Mid-South. Individual growers may be more or less impacted depending on whether pest pressure would necessitate multiple applications or only one during the pre-bloom and bloom period.

The total cost of a pre-bloom and bloom restriction is expected to be about $6.9 million per year nationally and could vary between $4.2 and $9.3 million per year. The restriction would affect about 1.2 million acres of cotton. Impacts would be concentrated in the Mid-South where the majority of neonicotinoid-treated cotton is located; total costs are estimated to be $5.0 million per year. Currently, neonicotinoid use during cotton bloom is relatively limited. If EPA were to restrict use only from the beginning of bloom through harvest, less than 500,000 acres would be affected and expected total cost is estimated to be about $1.7 million per year. A restriction between pinhead squaring and the beginning of bloom would cost cotton producers almost $5.2 million per year.

Other potential ways to reduce exposure of pollinators to neonicotinoid residues would be to reduce the maximum allowable label rates or to restrict aerial applications, which can result in drift of residues onto adjacent pollinator forage areas. Per-acre impacts are likely to be similar to the full pre-bloom and bloom restrictions, but these actions would affect fewer acres. For example, reducing application rates about 30 percent would affect about 624,000 acres at an expected cost of $2.3 million annually. A prohibition on aerial application would affect about 159,000 acres annually for a total annual cost of $659,000.

Impacts arise due to growers using alternative insecticides for control of key cotton pests including plant bugs and stink bugs. BEAD concludes that most growers currently relying on neonicotinoids during the pre-bloom and bloom periods would switch to organophosphate and/or synthetic pyrethroid pesticides. These alternatives can likely be used in a manner to achieve similar control to neonicotinoids; thus, yield effects are not anticipated, but pest control costs are

ED_006569M_00137204-00002

likely to increase. Given the capacity of synthetic pyrethroids to flare secondary pest outbreaks, the impacts of restricting neonicotinoids may be underestimated. BEAD concludes that the benefits of neonicotinoids are high during the pre-bloom and bloom period for cotton.

INTRODUCTION

FIFRA Section 3(g) mandates that EPA periodically review the registrations of all pesticides to ensure that they do not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary considering scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether effects are unreasonable, FIFRA requires that the Agency consider the risks and benefits of any use of the pesticide.

In general, during Registration Review, EPA conducts both human health and ecological risk assessments and issues them at the same time. Due to the role the neonicotinoid insecticides have occupied in the dialogue around pollinator health, EPA conducted specific pollinator risk assessments for clothianidin, dinotefuran, imidacloprid, and thiamethoxam, following the harmonized pollinator assessment framework developed by the Agency in collaboration with other regulatory entities (EPA, PMRA and CDPR, 2014). A preliminary bee risk assessment for imidacloprid was published in January 2016 (EPA, 2016); preliminary bee risk assessments for dinotefuran (EPA, 2017a) and for clothianidin and thiamethoxam (EPA, 2017b) were released in January 2017. Separately, EPA is evaluating the risks to other ecological taxa and to human health from these compounds.

As stated in the Registration Review schedule update for neonicotinoids (EPA, 2017c), risks to pollinators were identified in the preliminary pollinator-only risk assessments released in January 2016 (imidacloprid) and January 2017 (clothianidin, thiamethoxam, and dinotefuran). In determining whether or what risk mitigation is sought for any compound(s), EPA considers available information on both the risks and benefits, including consideration of available alternatives. Prior to implementing any risk management on the neonicotinoids, EPA seeks comment from stakeholders on the proposed regulatory approach. In developing risk management for the neonicotinoids, the Agency has identified areas where additional information would aid in reaching a risk management decision, including information on the benefits of neonicotinoid use. While EPA typically releases benefit assessments along with the proposed interim decisions, EPA is releasing and obtaining public comment on two completed draft benefit assessments, for cotton and for citrus, at an earlier stage of the registration review process. EPA anticipates that early input and/or information from the public on the benefits of these compounds will be helpful as the Agency evaluates and considers the risk and the benefits in developing what, if any, mitigation options might be needed to address risks to bees for the proposed interim decision.

EPA assesses the benefits of neonicotinoids by comparing the existing situation in which a cotton producer uses neonicotinoids to the counterfactual situation without neonicotinoids. In the absence of neonicotinoids, users will likely switch to alternative insecticides. Impacts may arise due to the higher cost and/or lower efficacy of these alternatives; that is, benefits of

ED_006569M_00137204-00003

neonicotinoids may be lower production costs and/or higher yields or quality. These impacts may be quantified in monetary terms. EPA considers both the benefits and the risks in determining whether risk mitigation is needed. EPA also considers the comparative risks to human health and the environment of the likely pest control alternatives in any risk management decision.

The preliminary bee risk assessments are based on data from Tier 1 studies (laboratory) and some Tier 2 studies (semi-field)[1]. The assessments found residues resulting from foliar applications to cotton at levels that could affect honey bee colonies, including applications conducted approximately 20 days prior to bloom and while the cotton is blooming (see, for example, Wagman et al., 2017). Applications prior to this point, including soil applications and use of neonicotinoid-treated seeds, do not pose the same level of risks to pollinators.

This memorandum presents information on the usage of the four nitroguanidine neonicotinoids in cotton. It analyzes the impacts to cotton growers who use neonicotinoid insecticides, if EPA were to restrict the use of the neonicotinoids during times when residues could be present at levels that may result in adverse effects to pollinators. A commonly recognized point in the development of the cotton plant is pinhead squaring, which is the formation of the floral bud. Squaring generally occurs about three weeks prior to full bloom. Cotton blooms continuously through harvest. This memo, therefore, analyzes the impacts to cotton growers if EPA were to restrict use of neonicotinoid insecticides between pinhead squaring and full bloom and between full bloom and harvest to reduce exposure to pollinators. The analysis also considers the impacts if EPA were to restrict aerial applications only during this period and if maximum allowable rates were reduced by about 30 percent.

METHODOLOGY

The unit of analysis for this assessment is an acre of cotton treated at least once with a neonicotinoid insecticide between pinhead squaring and harvest. BEAD considers several scenarios that vary by region. The benefits of neonicotinoid use are measured in comparison to the next best available pest control option in terms of increased pest control costs per acre or, if appropriate, losses in yield or quality of product. BEAD first identifies the primary pests targeted by growers when using a neonicotinoid. Data for this purpose comes from market research data (MRD), collected through annual surveys of growers conducted by a leading private research firm. Survey information is collected following a statistically valid approach. Alternative pest control options are identified using the same survey data as well as state university extension recommendations. The most likely methods of control growers using neonicotinoids would use in their place are identified using best professional judgement based on biological considerations and economic theory. For example, a less expensive insecticide would not generally be considered a likely option to replace the use of a neonicotinoid because growers are assumed to minimize cost to maximize profits; hence, if a less expensive insecticide provided the same benefits as the neonicotinoid, a rational farmer would not be using the neonicotinoid. A less expensive option is therefore presumed to provide less control or be otherwise unsuitable because of the extent of the pest pressure, the need to control secondary pests simultaneously, or some other constraint. However, less expensive options might be employed multiple times to

[1] A Tier 2 analysis has not been completed for dinotefuran

achieve the same level of control, at an increase in cost, or growers may have to incur some loss in yield or quality (price received) due to less pest control. In some cases, alternatives may be costlier than neonicotinoids and still not provide the same level of control. Information on chemical and application costs is available from the market survey data as well as crop budgets developed by the U.S. Department of Agriculture (USDA) and state university extension programs. Information on comparative performance of neonicotinoids and other insecticides may come from research trials conducted by various entities including registrants and state universities.

The increased cost per acre and/or reduced revenue per acre is then placed in the context of grower income to characterize the impacts of restrictions/benefits of the neonicotinoids. BEAD uses net operating revenue, defined as gross revenue per acre less operating costs per acre, as the measure of income. Data from USDA National Agricultural Statistics Service (NASS) are used to calculate average gross revenue per acre. USDA Economic Research Service (ERS) Commodity Costs and Return or state estimates are used to calculate the operating costs. Fixed costs, such as land rent, equipment depreciation, and overhead costs, are not included because allocating these costs on a per-acre basis is complex due to the variation in farm size and diversity in farm production. While often included in budgets for major commodities like cotton, fixed costs are often not included in other crop budgets. For consistency across use sites, BEAD relies on measures of net operating revenue, acknowledging that this measure overstates grower income and will underestimate the impact of restrictions on pesticide use, at least on an affected acre.

OTHER ASSESSMENTS

The Center for Food Safety has issued two literature reviews, one updating the other, on the costs and benefits of neonicotinoid seed treatments in several field crops. The updated review (Jenkins, 2016) cites a study by Knight et al. (2015) reporting positive but inconsistent yield effects from thiamethoxam seed treatments in cotton over two years. The study did not provide an estimate of average yield effects or monetize any estimated benefits. Foliar applications were not addressed.

AgInfomatics (Mitchell and Dong, 2015), on behalf of registrants of neonicotinoids, assessed the benefits of the chemicals in agriculture, including estimating the benefits in cotton, *i.e.*, the impacts of the complete loss of neonicotinoids. AgInfomatics estimated that cotton production costs in the absence of neonicotinoids would increase by about $2.20 per acre (Mitchell and Dong, 2015). Cost increases were estimated in comparison to other registered insecticides, based on target pests. These insecticides are assumed to be used in the same proportion as applied to acres not treated with neonicotinoids, essentially resulting in a comparison of the acre-weighted average costs. This approach may underestimate the cost of alternatives because it includes insecticides that are cheaper to use than neonicotinoids. As noted in the methodology section, a one-to-one replacement with cheaper insecticides may not be appropriate. AgInfomatics also estimated that yields would decrease by 0.7 percent in the absence of neonicotinoids (Mitchell and Dong, 2015). Estimates of yield effects were largely made by comparing neonicotinoid treatments to untreated controls, which likely overestimates the yield impact incurred if other insecticides are used in place of neonicotinoids. Given estimates of yield and price presented in

ED_006569M_00137204-00005

Table 1, below, the estimated yield loss is equivalent to about $5.60 per acre, nationally. The differing assumptions underlying the cost and yield estimates, where the cost estimate assumes the use of other insecticides while the yield loss estimate often does not, mean that the two estimates of value cannot be added together. AgInfomatics further estimated impacts, in a more general equilibrium approach, if all agricultural uses of neonicotinoids were prohibited. The general equilibrium approach incorporated the individual cost and yield estimates and accounted for changes in acreage and prices among multiple field crops; the estimated impacts to cotton amounted to about $5.40 per acre. Most of the impacts, however, were estimated to fall on processors; ultimately, growers were estimated to benefit from higher farm-gate prices.

USAGE OF NEONICOTINOIDS IN COTTON

Cotton is a major crop in the United States, with an average of 9.2 million acres harvested annually from 2010 to 2014 and a total production value averaging over $7.4 billion per year (USDA/NASS 2016). The primary growing region for upland cotton (*Gossypium hirsutum*) is from Texas in the west, throughout the southeast to the Atlantic Coast, extending as far north as Kansas and Missouri, although it is also grown in California and Arizona. Pima cotton (*Gossypium barbadense*) is a more valuable cotton with longer fibers. Pima cotton requires a longer growing season than upland cotton and is the dominant cotton grown in California, Arizona, and New Mexico, as well as parts of Texas.

The cotton regions are categorized by the National Cotton Council of America (Wrona et al., 1996) as follows (Figure 1):

- Southeast: Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia;
- Mid-South: Arkansas, Louisiana, Mississippi, Missouri, and Tennessee;
- Plains: New Mexico, Kansas, Oklahoma, and Texas;
- West: Arizona, California

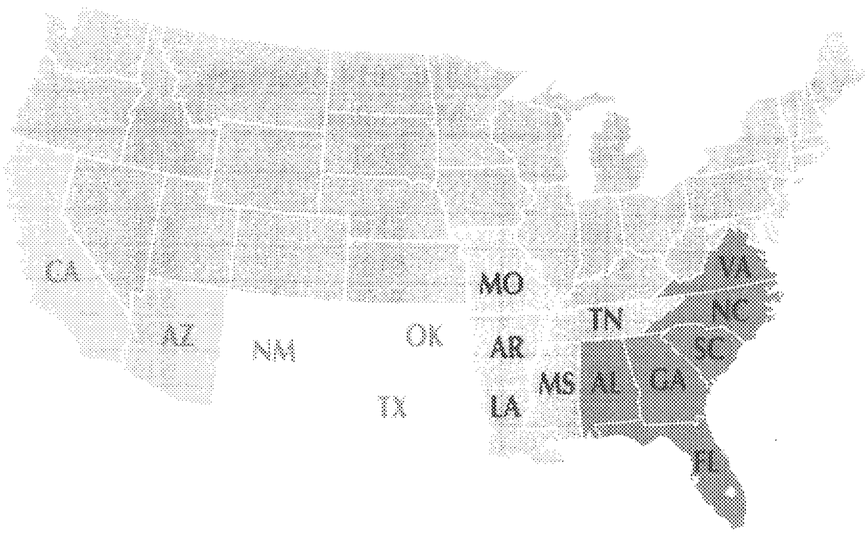

Figure 1. Cotton Regions Map (Wrona et al., 1996)

Table 1 shows the area harvested, production, and the value of production for both types of cotton, averaged over the years 2010-2014. Texas is the largest producer of cotton, both in terms of acreage and value, with Georgia second in both categories. The high value of production in the West reflects higher yields than other states, as well as higher value cotton grown.

Table 1. Acreage, Production, and Value of Cotton, 2010-2014 Averages.

State/Region	Harvested Acreage	Production (1,000 lbs)	Yield (lbs/acre)	Total Value [1] ($1,000)	Gross Revenue ($/acre)
Southeast [2]	2,766,000	2,376,672	859	2,177,765	787
Mid-South [3]	1,785,000	1,787,424	1,001	1,697,959	951
Plains [4]	4,206,000	2,754,096	655	2,389,812	568
West [5]	517,500	782,678	1,512	1,112,956	2,150
U.S. Total	9,274,500	7,700,870	830	7,378,492	796

Source: USDA/NASS, 2016 (QuickStats)

1 Value of cotton fiber and cottonseed.
2 Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia.
3 Arkansas, Louisiana, Mississippi, Missouri, Tennessee.
4 Kansas, New Mexico, Oklahoma, Texas.
5 Arizona, California.

Table 2 presents revenue and production costs, by region. Production in the Plains states tends to be lower input and lower cost, reflecting dry-land agriculture. Ginning costs tend to be correlated with yields. Because of such factors, net operating revenue – the difference between gross revenue and variable operating costs – is less variable across regions than gross revenue. Not included in variable operating costs are fixed costs of production such as land rent or mortgage, equipment depreciation, and overhead costs that depend on factors such as ownership, farm size, and the diversity of production. Thus, net operating revenue overstates grower income from cotton production.

Table 2. Revenue and Production ($/Acre), 2010-2014 Averages.

	Southeast	Mid-South	Plains	West
Gross Revenue	$787	$951	$568	$2,150
Operating Costs				
Seed	$108	$136	$75	$54
Fertilizer	$144	$123	$53	$151
Pesticides	$93	$107	$43	$244
Machinery	$88	$91	$96	$213
Labor (hired)	$14	$18	$13	$122
Custom Operations	$24	$31	$15	$72
Irrigation [1]	$0	$0	$0	$250
Ginning [2]	$125	$170	$73	$105

ED_006569M_00137204-00007

	Southeast	Mid-South	Plains	West
Total, Operating Costs	$597	$675	$367	$1,211
Net Operating Revenue	$190	$276	$201	$939

Source: USDA/NASS, 2016 (see Table 1), USDA/ERS, 2016a; Hutmacher et al., 2012

1 Irrigation costs for the West consist of the cost of water; for other regions, irrigation costs are subsumed under machinery costs.

2 Hutmacher et al. (2012) do not specify ginning costs; they state that 'cotton gins keep cottonseed' in lieu of ginning fees. Estimated value of cottonseed is $105/acre.

On average, about 6.4 million acres of cotton are treated with a neonicotinoid insecticide (Table 3). Given about 9.3 million acres of cotton cultivated each year (Table 1), BEAD estimates almost 69% of acres receive at least one application of a neonicotinoid. Accounting for multiple applications, there are nearly nine million acre-treatments of cotton with a neonicotinoid. Surveys of insecticide use in cotton report little or no usage of dinotefuran as of 2015; usage of clothianidin is also relatively low relative to imidacloprid and thiamethoxam.

Table 3. Average Annual Neonicotinoid Use [1], Cotton

Chemical	Base Acres Treated [2]	Total Acres Treated [3]	lb Applied	Average Application Rate [4] (lb/acre)
Clothianidin	262,000	281,000	14,400	0.051
Imidacloprid	2,506,000	3,223,000	192,000	0.060
Thiamethoxam	4,521,000	5,486,000	201,000	0.037
U.S. Total	6,378,000	8,990,000	408,000	0.045

Source: MRD, 2010-2014. Calculations subject to rounding.

1 Dinotefuran is registered for use on cotton, but usage is essentially non-existent.

2 Base Acres Treated (BAT) are acres treated at least once with any neonicotinoid. Because an acre of cotton may be treated with more than one neonicotinoid, the U.S. total BAT is less than the sum of the BAT for individual chemicals.

3 Total Acres Treated (TAT) accounts for acres treated multiple times, either by the same neonicotinoid or by multiple chemicals.

4 Averaged across all types of application methods.

Table 4 provides information about neonicotinoid use by application method. Seed treatments account for most of the use, by both acres treated and pounds applied. On about four percent of the acres planted with treated seeds, the seeds are treated with both imidacloprid and thiamethoxam. About one percent of the area receiving soil treatments are treated with two imidacloprid products. About 63,000 acres per year, on average, are treated with a combination of seed treatment and soil application at plant, or about one percent of the acres planted with neonicotinoid-treated seeds.

Table 4. Average Annual Neonicotinoid Use, Cotton, by Application Method

Application Method	Base Acres Treated [1]	Total Acres Treated [1]	lb Applied	Average Application Rate (lb/acre)	Number of Applications [1]
Seed Treatment	5,841,000	6,075,000	240,000	0.040	1.04
Soil Applied	97,500	98,600	14,500	0.147	1.01
Foliar Applied	1,636,000	2,816,000	153,000	0.054	1.72
U.S. Total	6,378,000	8,990,000	408,000	0.045	1.41

Source: MRD, 2010-2014.

1 Base Acres Treated are acres treated at least once per year. Total Acres Treated accounts for multiple applications. Average number of applications is total acres treated divided by base acres treated.

Foliar Usage

Based upon the Agency's preliminary risk assessment to bees, foliar applications of the neonicotinoid compounds pose a higher potential risk than other methods of application. If EPA were to consider restrictions on neonicotinoids to reduce exposure to bees, it would likely first consider restrictions on foliar applications, which account for about 25 percent of the base acres treated with neonicotinoids and almost 40 percent of the total amount of neonicotinoids applied to cotton, by volume. This assessment will focus, therefore, on foliar applications and specifically those occurring about 20 days prior to bloom and continuing through the bloom period.

Table 5 provides information about the timing of foliar applications. Per the National Cotton Council (NCC, undated), emergence occurs 4 to 9 days after planting and squaring begins 27 to 38 days later. Bloom begins 20 to 25 days after squaring. In total, cotton takes about 130 to 160 days from planting to harvest. Squaring is an easily identifiable, field relevant phenological stage at which to set a pre-bloom restriction on neonicotinoid use. Of cotton acres treated with foliar applications, approximately 73 percent of base acres and 68 percent of total acres treated are treated between squaring and harvest. Thiamethoxam is applied to about two-thirds of the acres treated after squaring while imidacloprid accounts for over half the neonicotinoid use in terms of pounds applied. There may be multiple foliar applications of a neonicotinoid throughout the year targeting various pests and applications of multiple neonicotinoids. For example, over 200,000 acres are treated with a neonicotinoid between squaring and bloom and again between bloom and harvest; hence, the sum of base acres treated between squaring and harvest is greater than base acres treated with at least one neonicotinoid over the entire period. The same chemical can also be used more than once within a crop stage. If the Agency were to restrict the foliar use of neonicotinoids in the pre-bloom and bloom periods, the latter lasting until harvest, it would affect over one million acres of cotton or about 12 percent of cotton acres.

ED_006569M_00137204-00009

Table 5. Average Annual Neonicotinoid Use, Cotton, by Foliar Application Timing

Application Timing	Base Acres Treated	Total Acres Treated	lb Applied	Average Application Rate (lb/acre)
Emergence to Squaring	632,000	892,000	50,300	0.056
Clothianidin	17,900	18,400	1,800	0.098
Imidacloprid	267,000	386,000	28,700	0.074
Thiamethoxam	373,000	488,000	19,800	0.041
Squaring to Bloom	993,000	1,444,000	76,200	0.053
Clothianidin	74,400	74,500	4,300	0.058
Imidacloprid	356,000	534,000	37,700	0.071
Thiamethoxam	630,000	835,000	34,100	0.041
Bloom to Harvest	340,000	481,000	26,600	0.055
Clothianidin	45,700	47,500	2,800	0.059
Imidacloprid	160,000	231,000	15,300	0.066
Thiamethoxam	169,000	201,000	8,400	0.042
Squaring to Harvest [1]	**1,120,000**	**1,924,000**	**103,000**	**0.053**
Clothianidin	103,000	122,000	7,100	0.059
Imidacloprid	460,000	766,000	53,000	0.069
Thiamethoxam	747,000	1,036,000	42,500	0.041
Total Foliar Application	**1,636,000**	**2,816,000**	**153,000**	**0.054**
Clothianidin	121,00	140,000	8,900	0.064
Imidacloprid	628,000	1,151,000	81,800	0.071
Thiamethoxam	1,047,000	1,524,000	62,300	0.041

Source: MRD, 2010-2014.

[1] Base acres treated between squaring and bloom may be treated again between bloom and harvest; thus, the sum of the two periods is greater than the total base acres treated over the squaring to harvest period. Because an acre of cotton may be treated with more than one neonicotinoid, the total BAT is less than the sum of the BAT for individual chemicals.

Table 6 presents the regional usage patterns of foliar applications. The Mid-South relies heavily on neonicotinoids – over 50 percent of the cotton crop treated – and accounts for nearly two-thirds of the total foliar-treated acres nationwide. Overall, the Plains states rely the least of the regions on neonicotinoids, with less than 10 percent of the crop treated; growers tend to use a lower rate, but multiple applications are common. Growers in the Plains do not report use of clothianidin as a foliar application and rarely rotate between imidacloprid and thiamethoxam. Growers in the West rely much more heavily on clothianidin for foliar applications than growers in other parts of the country.

ED_006569M_00137204-00010

Table 6. Average Annual Foliar Use of Neonicotinoids, Cotton, by Region

State/Region	Base Acres Treated (% of Acreage)	Total Acres Treated	lb Applied	Average Application Rate (lb/acre)	Acres Treated more than Once (% of Base)
Southeast [1]	324,000 (11.7%)	396,000	27,700	0.070	61,400 (19.0%)
Clothianidin	55,700 (2.0%)	74,000	4,500	0.061	18,300 (32.8%)
Imidacloprid	86,300 (3.1%)	125,000	15,800	0.127	36,400 (42.2%)
Thiamethoxam	191,000 (6.9%)	198,000	7,400	0.037	6,700 (3.5%)
Mid-South [2]	895,000 (50.1%)	1,807,000	94,300	0.052	538,000 (60.1%)
Clothianidin	1,600 (0.1%)	2,200	200	0.077	500 (33.3%)
Imidacloprid	417,000 (23.3%)	845,000	52,000	0.061	245,000 (58.8%)
Thiamethoxam	611,000 (34.2%)	960,000	42,100	0.044	293,000 (47.9%)
Plains [3]	305,000 (7.2%)	475,000	20,900	0.044	131,000 (43.0%)
Clothianidin	None reported				
Imidacloprid	77,500 (1.8%)	116,000	8,400	0.073	23,200 (29.9%)
Thiamethoxam	238,000 (5.6%)	359,000	12,400	0.035	108,000 (45.4%)
West [4]	113,000 (21.8%)	138,000	10,100	0.074	12,800 (11.4%)
Clothianidin	63,600 (12.3%)	64,300	4,200	0.066	600 (1.0%)
Imidacloprid	47,600 (9.2%)	66,200	5,600	0.085	12,200 (25.6%)
Thiamethoxam	7,400 (1.4%)	7,400	300	0.040	0
U.S. Total	1,636,000 (17.6%)	2,816,000	153,000	0.054	743,000 (45.4%)
Clothianidin	138,000 (1.5%)	140,000	8,900	0.064	19,500 (14.1%)
Imidacloprid	782,000 (8.4%)	1,151,000	81,800	0.071	317,000 (40.5%)
Thiamethoxam	1,162,000 (12.5%)	1,524,000	62,300	0.041	407,000 (35.0%)

Source: MRD, 2010-2014.

1 Alabama, Florida, Georgia, North Carolina, South Carolina. Data are not available for Virginia.

2 Arkansas, Louisiana, Mississippi, Missouri, Tennessee.

3 Kansas, Oklahoma, Texas.

4 Arizona, California. Data are not available for New Mexico.

ED_006569M_00137204-00011

Table 7 provides average annual neonicotinoid foliar use from squaring through harvest, which is the period of greatest potential exposure to bees. In total, about 1.2 million acres of cotton are treated at least once with a neonicotinoid during this period. About half of the 2.8 million total acre treatments are made in the square to bloom period – and the Mid-South accounts for over two-thirds of the acres treated during this stage, which lasts about three weeks (NCC, undated). Another 17 percent of total foliar-treated area is treated in the bloom to harvest period, which lasts ten to 14 weeks. Again, the Mid-South accounts for two-thirds of the treated acres.

Table 7. Average Annual Neonicotinoid Foliar Use, Squaring to Harvest, by Region

State/Region	Base Acres Treated	Total Acres Treated Square to Bloom	Total Acres Treated Bloom to Harvest
Southeast [1]	234,000	201,000	74,400
Clothianidin	40,100	23,100	34,900
Imidacloprid	48,100	32,300	23,500
Thiamethoxam	156,000	146,000	16,100
Mid-South [2]	707,000	996,000	301,000
Clothianidin		Negligible	
Imidacloprid	323,000	437,000	157,000
Thiamethoxam	469,000	559,000	142,000
Plains [3]	152,000	166,000	59,600
Imidacloprid	45,100	39,100	20,400
Thiamethoxam	115,000	127,000	39,200
West [4]	107,000	81,200	44,500
Clothianidin	61,500	51,200	10,700
Imidacloprid	43,500	26,200	30,100
Thiamethoxam	7,400	3,800	3,700
U.S. Total	1,200,000	1,444,000	480,000
Clothianidin	103,000	74,500	47,500
Imidacloprid	460,000	534,000	231,000
Thiamethoxam	747,000	835,000	201,000

Source: MRD, 2010-2014.

1 Alabama, Florida, Georgia, North Carolina, South Carolina. Data are not available for Virginia.

2 Arkansas, Louisiana, Mississippi, Missouri, Tennessee.

3 Oklahoma, Texas. Data are not available for Kansas.

4 Arizona, California. Data are not available for New Mexico.

Aerial Applications and Rate Distributions

Before estimating the impacts of a prohibition on the use of neonicotinoids after pinhead squaring and through harvest, the consequences of two less severe restrictions on use are briefly considered: prohibiting aerial applications and reducing application rates by about 30 percent.

EPA primarily assessed the risks to pollinators from on-field exposure, that is, resulting from pollinators foraging on the cotton crop. However, there are also risks associated with exposure from residues that may drift onto adjacent areas. This off-site exposure is greater for aerial applications than for applications made by ground equipment and prohibiting aerial applications would reduce this route of exposure. Aerial applications are not common, accounting for about 159,000 total acres treated per year or less than 10 percent of the total area treated foliarly in the period from squaring to harvest (Table 8). Most of the acres treated by air are in the Mid-South, although the proportion of acres treated by air in the region is below the national average. Aerial applications are relatively more common in the West. Aerial applications are typically made when field conditions do not allow for ground applications, either because of wet conditions or when the crop has developed to the point that ground equipment will damage plants and reduce yields. Very large fields may be treated by air because ground applications would be too slow to provide adequate coverage in a timely manner. Thus, a prohibition on applying neonicotinoids by air would largely result in growers using an alternative insecticide that could be applied by air. This is the impact assessed in the next section and results would be similar for an aerial prohibition, but would affect fewer acres.

Table 8. Aerial Application of Neonicotinoids, Square to Harvest only.

State/Region	Total Acres Treated	Acres Treated by Air (% of Total Acres Treated)
Southeast	276,000	negligible
Clothianidin	57,900	negligible
Imidacloprid	55,800	negligible
Thiamethoxam	162,000	negligible
Mid-South	1,300,000	98,800 (7.6)
Imidacloprid	594,000	44,000 (7.4)
Thiamethoxam	701,000	53,500 (7.6)
Plains	225,000	4,000 (1.8)
Imidacloprid	59,500	1,500 (2.6)
Thiamethoxam	166,000	2,500 (1.5)
West	126,000	56,000 (44.5)
Clothianidin	61,900	36,900 (59.6)
Imidacloprid	56,300	17,900 (31.7)
Thiamethoxam	7,400	1,200 (16.2)
U.S. Total	1,920,000	159,000 (8.3)
Clothianidin	122,000	38,100 (31.3)
Imidacloprid	766,000	63,400 (8.3)
Thiamethoxam	1,040,000	57,200 (5.5)

Source: MRD, 2010-2014.

The maximum allowable foliar application rate for neonicotinoid use on cotton varies by chemical. The maximum rate for clothianidin is 0.102 pounds of active ingredient per acre (lb a.i./acre); the highest rate permitted for imidacloprid is 0.35 lb a.i./acre; the maximum rate allowed for thiamethoxam is 0.0625 lb a.i./acre; and the maximum rate for dinotefuran is 0.134 lb a.i./acre. Reducing rates results in lower residues and lower exposure to pollinators. The immediate impacts of reducing maximum allowable rates are difficult to predict. If rates are lowered below that which is effective against target pests, growers must switch to alternative pesticides. The magnitude of such impacts are expected to be similar to those estimated in the next section, on a per-acre basis. Growers might also be able to combine neonicotinoids at lower rates with other insecticides, either in combination products or tank mixes, to address pest control needs at a lower cost than relying solely on an alternative chemical. These changes would only effect those acres that are treated near the maximum application rates currently allowed; to characterize the breadth of impacts, BEAD estimated the acreage affected by a rate reduction of about 30 percent. Relatively few acres treated with imidacloprid, around 45,000 acres or six percent of the acres treated between pinhead squaring and harvest, would be affected by a reduction in the maximum allowable rate to around 0.24 lb a.i./acre (Table 9). In contrast, similar reductions in clothianidin and thiamethoxam would impact a much higher proportion of treated acres. Over half a million acres, which accounts for more than half the acres treated between squaring and harvest, would likely be affected if the rate of thiamethoxam were reduced from 0.06 lb a.i./acre to 0.04 lb a.i./acre. Over one-third of the acres treated with clothianidin would be affected if the maximum allowable rate were to be reduced to 0.06 lb a.i./acre.

Table 9. Neonicotinoid Application Rate Distributions, Square to Harvest only.

State/Region	Total Acres Treated	Application Rate Distribution [1]
Southeast	276,000	
Clothianidin	57,900	4,100 acres (7% of area) treated at > 0.06 lb a.i./acre
Imidacloprid	55,800	4,300 acres (8% of area) treated at > 0.24 lb a.i./acre
Thiamethoxam	162,000	25,100 acres (16% of area) treated at > 0.04 lb a.i./acre
Mid-South	1,300,000	
Imidacloprid	594,000	29,600 acres (5% of area) treated at > 0.24 lb a.i./acre
Thiamethoxam	701,000	452,000 acres (65% of area) treated at > 0.04 lb a.i./acre
Plains	225,000	
Imidacloprid	59,500	2,600 acres (4% of area) treated at > 0.24 lb a.i./acre
Thiamethoxam	166,000	55,900 acres (34% of area) treated at > 0.04 lb a.i./acre

State/Region	Total Acres Treated	Application Rate Distribution[1]
West	126,000	
Clothianidin	61,900	37,000 acres (60% of area) treated at > 0.06 lb a.i./acre
Imidacloprid	56,300	8,600 acres (15% of area) treated at > 0.24 lb a.i./acre
Thiamethoxam	7,400	3,700 acres (49% of area) treated at > 0.04 lb a.i./acre
U.S. Total	1,920,000	
Clothianidin	122,000	42,700 acres (35% of area) treated at > 0.06 lb a.i./acre
Imidacloprid	766,000	45,100 (6% of area) treated at > 0.24 lb a.i./acre
Thiamethoxam	1,040,000	537,000 (52% of area) treated at > 0.04 lb a.i./acre

Source: MRD, 2010-2014. (Need to round)

1 Maximum label rates are: Clothianidin, 0.102 lb a.i./acre; Dinotefuran, 0.134 lb a.i./acre; Imidacloprid, 0.35 lb a.i./acre; Thiamethoxam, 0.0625 lb a.i./acre.

BENEFITS OF NEONICOTINOIDS/IMPACTS OF POTENTIAL USE RESTRICTIONS

This section estimates the impact if EPA were to prohibit the use of neonicotinoid insecticides from pinhead squaring through harvest, corresponding to pre-bloom and bloom periods when exposure to pollinators are expected to be highest. As stated above, the unit of analysis is an acre treated with a neonicotinoid. BEAD first identifies the likely pests targeted by a neonicotinoid application and then potential alternative pest control methods; both pests and potential alternatives may vary by region due to agronomic and economic conditions. Based on biological considerations and economic theory, BEAD determines the most likely method that would be used to replace the neonicotinoid insecticide. In this situation, alternative insecticides can largely replace neonicotinoids without compromising control; yield impacts are not anticipated. However, alternative control methods are generally costlier than are neonicotinoids; chemical costs are greater or alternatives must be used more frequently. BEAD estimates the most likely, or expected, impact per acre given the difference in cost between the neonicotinoid and the likely alternative. The impact may be more or less severe on any given acre; however, extrapolating the expected impact across total acres treated with neonicotinoids provides a reasonable estimate of the total regional and national impacts.

Target Pests

The pests targeted with neonicotinoids differ somewhat across regions and, to a lesser extent, chemicals (Table 10). In general, plant bugs are the most common targets. Stink bugs are somewhat more common targets in the Southeast than in the Mid-South and Plains states. In the Plains states, unlike other regions, the primary target pest is the fleahopper. Aphids, at least in the Southeast and Plains, are a common target of imidacloprid, generally at a higher application rate than applications for plant or stink bugs but at lower rates than for fleahoppers; in the West, aphids seem to be secondary pests of applications that primarily target plant bugs, referred to as

Lygus bug by respondents from the West. Aphids are likely not primary targets of insecticide applications because aphids often build to moderate population size in cotton fields before crashing naturally due to a persistent fungal epizootic infection (UGA, 2016). Bollworms appear as relatively frequent targets of imidacloprid in the Southeast and Mid-South, respectively, but do not otherwise appear to be drivers of neonicotinoid use. Bollworms are typically controlled by cotton cultivars that are modified with the genetic material from strains of the bacterium *Bacillus thuringiensis* (*Bt*) to produce a natural toxin. However, supplemental insecticide treatments may be needed given low susceptibility to *Bt* in this pest and arising resistance concerns regionally (UGA 2016; Tabashnik et al. 2013).

Table 10. Neonicotinoid Target Pests, Foliar Use, Square to Harvest, by Region

		% of Neonicotinoid Treated Acres [1]			
Region	**Pest**	**Clothianidin**	**Imidacloprid**	**Thiamethoxam**	**All Neonicotinoids**
Southeast [2]	Area Treated	57,900	55,800	162,000	276,000
	Aphids	negligible	37%	2%	9%
	Stink Bugs	41%	37%	20%	28%
	Plant Bugs	45%	46%	81%	66%
	Boll Worm	11%	22%	2%	8%
Mid-South [3]	Area Treated	negligible	594,000	701,000	1,300,000
	Aphids	-	13%	8%	10%
	Stink Bugs	-	9%	6%	8%
	Plant Bugs	-	84%	95%	90%
	Boll Worm	-	17%	3%	10%
Plains [4]	Area Treated	negligible	59,500	166,000	225,000
	Aphids	-	39%	29%	32%
	Stink Bugs	-	24%	9%	13%
	Plant Bugs	-	21%	2%	7%
	Fleahopper	-	40%	81%	70%
West [5]	Area Treated	61,900	56,300	7,400	126,000
	Aphids	35%	39%	negligible	35%
	Plant Bugs	89%	71%	16%	76%

Source: MRD, 2010-2014.

1 Percentages do not sum to 100 because multiple pests may be targeted with a single application.

2 Alabama, Florida, Georgia, North Carolina, South Carolina. Data are not available for Virginia.

3 Arkansas, Louisiana, Mississippi, Missouri, Tennessee.

4 Oklahoma, Texas. Data are not available for Kansas.

5 Arizona, California. Data are not available for New Mexico.

There are anecdotal reports of dinotefuran used against Silverleaf whitefly in the Southeast (Roberts, 2017). The Silverleaf whitefly is a pest that only sporadically reaches damaging levels.

Nationwide cotton losses to arthropod pests reduced overall yields by 2.6 percent from 2011-2015 (Mississippi State, 2011-2015). Stink bugs and plant bugs are always in the top-ranked pests. Plant bugs and stink bugs reduced yield on average by 0.8 percent and 0.5 percent, respectively (Mississippi State 2011-2015). These losses occur with existing control measures. Neonicotinoids are a key tool for control of these top cotton pests (UGA, 2016).

Southeast Alternatives and Impacts

Table 11 presents information about the pests targeted by neonicotinoids by Southeast cotton growers and alternative active ingredients that are also reported to be used against them. Of the four pests identified in Table 10, stink bugs are the most commonly targeted, in terms of acres treated reflecting both the number of acres infested and the frequency with which growers must treat. While a common pest targeted by neonicotinoids, the neonicotinoids play only a small role in stink bug control, accounting for only about 3% of the acres treated for the pests. Production guides recommend primarily pyrethroids and some organophosphates for stink bug control (UGA, 2016). Neonicotinoids, especially thiamethoxam, are relatively more important for control of plant bugs. Dicrotophos and/or bifenthrin are the most common chemical means of controlling both stink and plant bugs (MRD, 2010-2014; UGA, 2016). Novaluron, which is roughly $2/acre more expensive than thiamethoxam, might be an option to control immature stink and plant bugs (UGA, 2016). Combinations of acephate or dicrotophos with bifenthrin and bifenthrin with zeta-cypermethrin might also be feasible (Emfinger et al., 2001; Willrich et al., 2003; Snodgrass et al., 2005). These combinations cost, on average, $1-4/acre more than thiamethoxam (MRD 2010-2014).

As noted in Table 10, imidacloprid is frequently used to target the bollworm, but it accounts for a very small proportion of acres treated for the pest. Bollworm has historically been targeted by plant-incorporated *Bt* which accounts for 84% of U.S. cotton, by acreage (USDA/ERS, 2016b). However, low resistance concerns may lead to increased importance of insecticide applications for use against bollworms (Tabashnik et al., 2013). Per usage data, the typical imidacloprid product is a combination with cyfluthrin, a synthetic pyrethroid. The most common chemical used against the bollworm in Southeast cotton is lambda-cyhalothrin (MRD, 2010-2014). Lambda-cyhalothrin is also a synthetic pyrethroid and would be unlikely to replace imidacloprid in combination with another pyrethroid. Additionally, bollworm resistance to synthetic pyrethroids has been documented in the Southeast (UGA, 2016). A more likely replacement would be a combination of acephate and bifenthrin, which is about $2/acre more expensive than the imidacloprid and cyfluthrin mixture.

Aphids are not a major pest in the Southeast, in terms of total acres treated, but neonicotinoids – especially imidacloprid – are the dominant chemical used for their control. Aphids are likely not the primary target of insecticide sprays because populations usually crash naturally in June after a naturally occurring fungus infects the pest (UGA, 2016). Extension experts have also indicated to BEAD that aphids rarely cause major impacts in the Southeast unless cotton is under drought stress (Reed and Smith, pers. comm., 2017). Dicrotophos and bifenthrin are also frequently used against aphids, although the main target pest for dicrotophos is thrips (MRD, 2010-2014). In the absence of neonicotinoids, lambda-cyhalothrin or another synthetic pyrethroid may be the most likely alternative growers would use for aphids. Per usage data, lambda-cyhalothrin would cost nearly $1/acre more than imidacloprid (Table 11).

ED_006569M_00137204-00017

Table 11. Insecticides Used for Neonicotinoid Target Pests, Square to Harvest, Southeast

Pest	Total Area Treated [1]	Active Ingredient	% Total Acres Treated [2]	Average $/acre
Aphids	50,800	Imidacloprid	41%	$6.40
		Dicrotophos	23%	$2.30
		Bifenthrin	7%	$1.80
		Thiamethoxam	6%	$6.50
		Lambda-cyhalothrin	5%	$7.10
Stink Bugs	3,600,000	Dicrotophos [3]	45%	$4.30
		Bifenthrin [3]	24%	$4.50
		Dicrotophos + Bifenthrin	5%	$6.80
		Novaluron	5%	$8.00
		Thiamethoxam	1%	$4.20
		Clothianidin	1%	$7.50
		Imidacloprid	1%	$4.30
Plant Bugs	1,010,000	Dicrotophos	37%	$3.30
		Bifenthrin [4]	28%	$3.10
		Thiamethoxam	13%	$6.30
		Novaluron	6%	$8.20
		Clothianidin	3%	$7.20
		Imidacloprid	3%	$4.20
		Acephate + Bifenthrin	<1%	$7.60
		Bifenthrin + Zeta-Cypermethrin	<1%	$10.50
Bollworm	1,080,000	Lambda-Cyhalothrin	44%	$4.30
		Bifenthrin	31%	$4.00
		Novaluron	16%	$8.10
		Cyfluthrin [5]	6%	$4.50
		Imidacloprid [6]	2%	$3.80
		Acephate + Bifenthrin	3%	$7.60

Source: MRD (2010-2014)

1 Total area, across all insecticides, treated for the pest during the period from squaring to harvest.

2 Percent of acres treated, rate, and cost includes tank mixes with other products, unless otherwise noted. Due to mixtures, sum of percentages may exceed 100.

3 Excluding mixtures of dicrotophos and bifenthrin.

4 Excluding mixtures with acephate and zeta-cypermethrin.

5 Stand-alone product.

6 Only applied as part of combination product with cyfluthrin. Average total chemical cost of product is $5.60/acre.

BEAD estimates that the total impact if EPA were to restrict neonicotinoid usage during the squaring to harvest (pre-bloom through the blooming periods) would be almost $650,000 per year (Table 12) in the Southeast. Most of the impact stems from higher insecticide costs for control of plant or stink bugs, which would likely be a combination of bifenthrin with an organophosphate such as dicrotophos or acephate. Approximately 234,000 cotton acres in the Southeast are treated annually at these stages (Table 7), some more than once, with an estimated average cost per acre of around $2.80/year. Cost increases for alternative insecticides could range from as low as $1.00/acre for aphid control to $4 - $5/acre for a grower who would normally make an application of a neonicotinoid for plant or stink bug control and another application for aphid control.

Table 12. Impacts of Neonicotinoid Restrictions, Square to Harvest, Southeast

	Baseline	Aphid Control	Plant/Stink Bugs	Bollworm
Gross Revenue ($/acre)	787	787	787	787
Operating Costs ($/acre)				
Pesticides [1]	93	94	94-97	95
Other Costs	504	504	504	504
Net Operating Revenue ($/acre)	190	189	186-189	188
Loss as Percent of Net		0.5%	0.5-2.1%	1.1%
Total Acres Affected	276,000	23,800	240,000	12,400
Total Annual Cost	$649,000	$23,800	$600,000	$24,800

Source: See Tables 1 and 2. Additional pesticide cost from Table 10. Table numbers are rounded.

1 Baseline pesticide costs include use of neonicotinoid; for aphid and bollworm control, a synthetic pyrethroid would likely be used in the absence of neonicotinoids; bifenthrin in combination with an organophosphate would likely be used for plant and/or stink bug control.

The estimated impact for plant and stink bug control assumes that, over 240,000 acres treated for those pests, the average cost will tend toward the mid-point of the range of likely additional insecticide cost. Impacts on plant and stink bug control could range from $240,000 per year, if growers incur costs at the low end of the range for all treated acres, to $1.2 million per year if all growers face costs at the upper end of the range. Accounting for all pests, impacts could range from $289,000 to $1.25 million per year, but the extremes of the range are unlikely; annual costs are expected to average about $649,000. The average impact is estimated to be about $2.40 per treated acre or about 1.2 percent of net operating revenue. About 46,000 acres of cotton are treated twice during the squaring to bloom period; expected impacts would be about $4.70 per acre. Total loss to the region can be apportioned between the period between pinhead squaring and bloom, when a total of about 201,000 acre treatments are made, and the remainder of the season when about 74,400 acre-treatments are made (Table 7). Impacts from a pre-bloom restriction alone would be about $473,000 per year and about $175,000 per year from a restriction on applications beginning at bloom.

Aerial restrictions would have little impact on Southeast cotton producers since neonicotinoids are rarely applied via air in the region (Table 8). Cotton producers in the Southeast also tend to apply neonicotinoids at less than the maximum label rates; hence, reductions in the label rates would affect about 33,500 acres per year (Table 9). Impacts per acre would likely still be about $2.40 per acre, but the total loss to the region would be around $80,000 per year.

ED_006569M_00137204-00019

Uncertainties

Some potential alternatives, including acephate and lambda-cyhalothrin, may cause outbreaks of mites later in the season (Gore and Cachot, personal communication, 2017). This tends to be less of a problem with alternatives such as dicrotophos and bifenthrin. In fact, few growers in the Southeast report treating for mites, averaging less than 65,000 acres of cotton per year. Those who do treat for mites largely report using dicrotophos and bifenthrin, although the primary pest would be plant or stink bug (MRD, 2010-2014). Thus, mite outbreaks resulting from the use of alternatives for neonicotinoids are likely to be rare. On average, mite control costs about $6.70 per acre in the Southeast (MRD, 2010-2014), so if an outbreak occurred, impacts on the affected area would more than double in comparison to the direct costs of replacing a neonicotinoid treatment.

Silverleaf whiteflies are a sporadic pest concern in Southeast cotton production that can sometimes necessitate insecticide treatment in the periods between pinhead squaring and bloom and between bloom harvest. Dinotefuran is an effective material for control (Roberts, pers. comm., 2017). As noted above, usage of dinotefuran in cotton is low to negligible (MRD, 2010-2014); some acres, however, could be negatively impacted if dinotefuran could not be used after pinhead squaring.

Mid-South Alternatives and Impacts

Table 13 presents information on control options for the main pests targeted by neonicotinoids in the Mid-South. Unlike the Southeast, plant bugs are the most important of the target pests, in terms of the total acres treated for control while stink bugs are relatively less of a problem. Bollworms account for about the same number of acres treated as stink bugs. Likewise, resistance issues and low susceptibility of bollworms to Bt cotton drive supplemental sprays (Tabashnik et al. 2013). Aphids are less of a problem than the other three pests, but appear relatively more problematic in the Mid-South than in the Southeast. Natural enemies often control aphid populations in the Mid-South, and aphids are often controlled by default from the management of plant bugs, which is generally more chemically intensive in the Mid-South relative to other regions (Stewart, pers. comm., 2017). However, aphid treatment may become necessary if cotton plants are stressed from other factors, like drought, as well (UT, 2016). Thiamethoxam and imidacloprid are commonly used for all four pests, either alone or in combination with other chemicals such as synthetic pyrethroids or novaluron.

Acephate and dicrotophos, often in combination with synthetic pyrethroids, are the primary tools growers use for plant bug and stink bug control in the Mid-South. If neonicotinoids cannot be used in the pre-bloom and especially the bloom period, growers will have limited options for control of plant bugs. The capacity for growers to make more applications of organophosphate/pyrethroid combinations could be limited by seasonal rate restrictions. Growers using neonicotinoids might be able to incorporate oxamyl into their system, although current usage is relatively low; the cost may be similar to thiamethoxam and about $3.20/acre more than imidacloprid (MRD, 2010-2014). Acetamiprid is not widely used for control of plant bugs in the Mid-South, but it is used against stink bugs and might be an alternative for both pests, at an added cost of $2-$5/acre (MRD, 2010-2014).

Bollworm control relies on a similar suite of chemicals; pyrethroids such as bifenthrin, lambda-cyhalothrin, and cyfluthrin are more common in terms of acres treated, but they are frequently mixed with organophosphates like acephate and dicrotophos. Pyrethroid insecticides are recommended less frequently as resistance to cypermethrin becomes more widespread (UGA, 2016). As stand-alone products, per-acre costs are substantially higher due to the need for a higher application rate. In the absence of neonicotinoids, growers will face difficult choices in terms of managing plant bugs and stink bugs as well as potentially bollworm. An alternative for bollworms might be chlorantraniliprole, which is $7-$9/acre more expensive than the neonicotinoids (MRD, 2010-2014; Table 13).

As with the Southeast, the neonicotinoids are a tool for aphid control. Sulfoxaflor was a common control tool, but the registration was recently vacated. OPs are also used, but additional use of acephate or dicrotophos to replace the neonicotinoids may be problematic due to seasonal limits on both chemicals. It should be noted that aphids are not often the primary target of insecticide applications as they are often kept below economic thresholds by natural enemies (UT, 2016). The most likely alternative is acetamiprid, which is about $2-$4/acre more expensive than the neonicotinoids (MRD, 2010-2014; Table 13).

Table 13. Insecticides Used for Neonicotinoid Target Pests, Square to Harvest, Mid-South

Pest	Area Treated Annually	Active Ingredient	% Total Acres Treated [1]	Average $/acre
Aphids	404,000	Imidacloprid	22%	$4.70
		Thiamethoxam	20%	$7.10
		Acetamiprid	19%	$8.90
		Dicrotophos	16%	$5.50
		Acephate	15%	$3.20
Stink Bugs	989,000	Bifenthrin	25%	$3.40
		Acephate	19%	$3.90
		Imidacloprid	19%	$4.10
		Thiamethoxam	15%	$6.80
		Acetamiprid	8%	$8.90
Plant Bugs	5,480,000	Acephate [2]	54%	$4.50
		Dicrotophos	37%	$4.30
		Thiamethoxam	36%	$6.90
		Bifenthrin	36%	$3.80
		Imidacloprid	24%	$3.80
		Novaluron	22%	$6.80
		Oxamyl	8%	$7.00
		Acephate + synthetic pyrethroid	22%	$7.70-$8.20

ED_006569M_00137204-00021

Pest	Area Treated Annually	Active Ingredient	% Total Acres Treated [1]	Average $/acre
Bollworm	1,170,000	Bifenthrin	39%	$3.60
		Lambda-cyhalothrin	33%	$4.00
		Dicrotophos	25%	$4.20
		Cyfluthrin	20%	$2.90
		Acephate [2]	16%	$4.40
		Imidacloprid	15%	$5.00
		Thiamethoxam	5%	$6.70
		Acephate + synthetic pyrethroid	9%	$7.90-$8.10
		Chlorantraniliprole	3%	$14.10

Source: MRD (2010-2014)

1 Percent of acres treated, rate, and cost includes tank mixes with other products, unless otherwise noted. Due to mixtures, sum of percentages may exceed 100.

2 Excluding mixtures with synthetic pyrethroids.

The Mid-South would face relatively heavy impacts if EPA were to restrict neonicotinoid usage from pinhead squaring through harvest (Table 14). BEAD estimates the total costs to be around $5 million/year from increased cost of insecticides for control of plant and stink bugs as well as aphids and boll worms. There are around 707,000 acres of cotton treated in the Mid-South during the pre-bloom to harvest period, often more than once (Table 7). Increases in per-acre costs could range from $2-$4 for aphid control to $9-$14 for growers treating for plant or stink bug and for bollworm (Table 13). On average, the impacts are estimated to be around $7.10/acre annually or more than 2.5 percent of the average net operating revenue for an acre of cotton.

Table 14. Impacts of Neonicotinoid Restrictions, Square to Harvest, Mid-South

	Baseline	Aphid Control	Plant/Stink Bugs	Boll Worm
Gross Revenue ($/acre)	951	951	951	951
Operating Costs ($/acre)				
Pesticides [1]	107	109-111	109-112	114-116
Other Costs	568	568	568	568
Net Operating Revenue ($/acre)	276	272-274	271-274	267-269
Loss as Percent of Net		0.7-1.4%	0.7-1.8%	2.5-3.3%
Total Acres Affected	1,300,000	131,000	1,050,000	123,000
Total Annual Cost	$5,040,000	$393,000	$3,660,000	$984,000

Source: See Tables 1 and 2. Additional pesticide cost from Table 13.

1 Baseline pesticide costs include use of neonicotinoid; additional costs are based on the use of acetamiprid for aphid, acetamiprid or bifenthrin in combination with an organophosphate for plant and/or stink bug control, and chlorantraniliprole for boll worm.

The estimated annual impact represents the midpoints of the ranges of cost increases, assuming that, over hundreds of thousands of treated acres, the midpoint represents the average increase in insecticide cost. If all growers incur costs at the low end of the ranges, total annual impacts are around \$3.2 million per year. If all growers incur costs at the high end of the ranges, total annual impacts are nearly \$6.9 million per year. Estimated costs are likely to average slightly more than \$5.0 million per year. Average impact is about \$3.90 per treated acre, but most of the acres treated with neonicotinoids are acres treated twice. Users, therefore, would face average cost increases of about \$7.80/acre or 2.8 percent of net operating revenue. Given about 996,000 total acres treated between pinhead squaring and the beginning of bloom (Table 7), costs of restricting applications in this period alone are likely to be nearly \$3.9 million per year. On average, there are 301,000 total acres of cotton treated with neonicotinoids from the beginning of bloom through harvest; an application restriction for this period only would likely cost nearly \$1.2 million per year.

An aerial restriction would affect about 98,800 acres (Table 8); such a restriction would cost to the region an estimated \$383,000 per year. Reductions in the maximum label rates would affect about 483,000 acres at a cost of about \$1.9 million per year.

Uncertainties

Use of alternatives such as acephate and many synthetic pyrethroids can result in outbreaks of mites later in the season (Gore and Cachot, personal communication, 2017). Thus, some growers may need an additional subsequent application of a miticide as a result of switching from a neonicotinoid for plant or stink bug control. Abamectin is the most commonly used miticide for cotton in the Mid-South; etoxazole and fenpyroximate are also used (MRD, 2010-2014). Per acre costs for these alternatives range between approximately \$7 to \$16 per acre (MRD, 2010-2014). Thus, a miticide application resulting from an outbreak caused by a neonicotinoid alternative could double the impact on affected acres.

Insecticide resistance issues are a defining issue for tarnished plant bug control in the Mid-South (Stewart, Gore, Cachot, et al., personal communication, 2017). While restrictions of neonicotinoid insecticide usage would have immediate substitution costs, in cases where pyrethroid resistance occurs, alternatives may be inadequate to achieve full control resulting in yield or quality losses. Neonicotinoid restrictions will almost certainly increase selection pressure and exacerbate resistance problems in the Mid-South.

Year-to-year variation in pest pressure may also result in substantial variation in the impacts of neonicotinoid restrictions. In years of high plant bug pressure, growers may need ten or more insecticide applications over the season (Gore and Cachot, personal communication, 2017). In the absence of neonicotinoids, seasonal limits on organophosphate alternatives would likely constrain a grower's ability to control plant bugs for the entire season, resulting in yield or quality losses.

Plains Alternatives and Impacts

Cotton production in the Plains states tends to be more land extensive and less input intensive than in other regions. Yields are lower, but production costs are also lower. The drier climate may provide a relatively favorable environment in that insect pest pressure is lower than in the Southeast and Mid-South; despite greater acres grown than in the other regions, acres treated for insects targeted by neonicotinoids is far lower. In terms of total acres treated during the pre-bloom and bloom periods, fleahoppers are the primary pest of those targeted by neonicotinoids with stink bugs and aphids close behind (MRD, 2010-2014; Table 15). Extension experts from Texas confirmed that fleahoppers tend to drive cotton pest management in Texas more than stink bugs or aphids (Kerns, pers. comm., 2017). Observed application rates for fleahopper and aphid are essentially the same, especially for thiamethoxam applications, and it is likely that the two pests are often targeted with a single application (MRD, 2010-2014). Plant bugs are a relatively small pest problem in comparison, with less than 40,000 total acres treated annually; rates used for stink and plant bugs are somewhat higher than those used for fleahopper and aphids (MRD, 2010-2014).

Acephate is the most widely used insecticide for fleahopper control. Fleahopper populations rarely reach economic thresholds and treatment is rarely justified unless the pest delays square set (Stevenson and Matocha, 2005). The average rate used for fleahopper control is lower than that used for other pests, making it an inexpensive option. Thiamethoxam, although one of the more expensive tools, is used on about a fourth of the acres treated for fleahopper. Given that thiamethoxam is, on average, more expensive than acephate, dicrotophos, and oxamyl, BEAD assumes growers who rely on thiamethoxam find use of the cheaper chemicals infeasible for some reason. It's possible that these growers face seasonal limits on the use of the OPs and oxamyl or there is some other constraint on their use. Thiamethoxam may be selected because it controls other pests as well. The most likely alternative in place of the neonicotinoids may be acetamiprid, which would cost $2-$4/acre more than thiamethoxam or imidacloprid (Table 15; MRD, 2010-2014).

Although the neonicotinoids are not major tools for stink bug control in the Plains, growers appear to have limited options in the absence of neonicotinoids. On average, the cost of synthetic pyrethroids is lower than the cost of neonicotinoids, suggesting as discussed in the methodology section, that they would not be likely alternatives, at least as a simple replacement. Neonicotinoids may have some advantages, such as a longer residual effect. Some pests like cotton bollworm are becoming increasingly resistant to pyrethroids (UGA, 2016). In addition, farmers may avoid pyrethroid applications because of their known association with secondary pest outbreaks, like flaring aphid populations (Reisig and Godfrey, 2010). Multiple applications of a pyrethroid may be necessary for stink bug control; data also indicate some growers using relatively high rates of pyrethroids, with associated higher chemical cost (Table 15; MRD, 2010-2014). Neonicotinoids are relatively more important for plant bug control, but plant bugs are a very minor pest in terms of acres treated.

Neonicotinoids are the primary control method for aphids in the Plains states. Aphid populations rarely justify insecticide treatment as natural enemies often control this pest (Stevenson and Matocha, 2005). Aphids may require treatment if threshold levels are exceeded during late bloom to prevent sooty mold (Stevenson and Matocha, 2005). Acetamiprid, which is also widely used, is the most likely alternative (MRD, 2010-2014). As with fleahopper control, switching to acetamiprid would likely cost $2-$4/acre more than thiamethoxam or imidacloprid (Table 15; MRD, 2010-2014).

Table 15. Insecticides Used for Neonicotinoid Target Pests, Square to Harvest, Plains

Pest	Area Treated Annually	Active Ingredient	% Total Acres Treated [1]	Average $/acre
Aphids	224,000	Thiamethoxam	31	$6.40
		Acetamiprid	23	$8.50
		Acephate	16	$7.00
		Imidacloprid	13	$4.30
Stink Bugs	364,000	Bifenthrin	50	$4.70
		Dicrotophos	32	$4.20
		Thiamethoxam	7	$6.00
		Lambda-cyhalothrin	6	$3.40
		Imidacloprid	4	$7.10
Plant Bugs	36,900	Imidacloprid	23	$4.00
		Acephate	17	$3.30
		Thiamethoxam	14	$7.60
		Dicrotophos	11	$4.00
		Lambda-cyhalothrin	10	$6.10
		Bifenthrin	9	$4.50
		Oxamyl	4	$10.00
Fleahopper	654,000	Acephate	43	$2.80
		Thiamethoxam	25	$6.40
		Oxamyl	13	$4.50
		Dicrotophos	13	$3.10
		Acetamiprid	7	$8.20
		Imidacloprid	5	$4.30

Source: MRD (2010-2014)

1 Percent of acres treated, rate, and cost includes tank mixes with other products, unless otherwise noted. Due to mixtures, sum of percentages may exceed 100.

Table 16 presents the estimated impacts to cotton growers in the Plains region if the use of neonicotinoids in the period from pinhead squaring to harvest was prohibited. Increases in the cost of insect control are anticipated to result in annual losses of over $600,000 (Table 16). Around 152,000 cotton acres receive at least one neonicotinoid application in the Plains region (Table 7), implying an average impact to growers of about $3.00/acre per year. Losses could range from about $1.00 to $2.00 per acre, due to increased cost for plant or stink bug control, if two applications of synthetic pyrethroids, *e.g.*, lambda-cyhalothrin, are used to replace one application of a neonicotinoid, to $2.00 to $4.00 per acre for an application of acetamiprid for control of fleahopper and/or aphids.

Table 16. Impacts of Neonicotinoid Restrictions, Square to Harvest, Plains

	Baseline	Aphid and/or Fleahopper	Plant/Stink Bugs
Gross Revenue ($/acre)	572	572	572
Operating Costs ($/acre)			
Pesticides [1]	43	45-47	44-45
Other Costs	324	324	324
Net Operating Revenue ($/acre)	205	201-203	203-204
Loss as Percent of Net		1.0-2.0%	0.5-1.0%
Total Acres Affected	225,000	179,200	45,800
Total Annual Cost	$606,000	$538,000	$68,700

Source: See Tables 1 and 2. Additional pesticide cost from Table 14.

1 Baseline pesticide costs include use of neonicotinoid; additional costs are based on the use of acetamiprid for aphid and fleahopper, and multiple applications of synthetic pyrethroids for plant and/or stink bug control.

Given the likely range of costs from changes in insecticides, the total regional impact could range from $404,000 to $808,000 annually. Over all the affected acres, BEAD assumes the average cost per acre is represented by the mid-points of the ranges with the total impact likely to be about $606,000 per year. Average cost per treated acre is about $2.70 or 1.3 percent of net operating revenue. There are around 152,000 acres treated at least once (Table 7) and about one third are treated twice during the period from pinhead squaring to harvest. Impacts would be about double for those acres. As in other regions, total acres treated are greater in the period prior to bloom than during bloom, about 166,000 and 60,000 respectively, on average (Table 7). Impacts of a pre-bloom restriction alone would average about $446,000 per year and, for a bloom restriction, about $161,000 per year.

Only about 4,000 acres per year are treated aerially; total cost to the region of a restriction on aerial applications would, therefore, be low. A reduction in the maximum label rate of about 30 percent, however, would affect about 58,500 acres per year at a cost to the region of around $158,000 annually.

Uncertainties

Applications of acephate and synthetic pyrethroids can result in mite outbreaks (Gore and Cachot, personal communication, 2017), and some growers may incur additional treatment costs if additional miticide sprays are necessary due to the use of neonicotinoid alternatives. The most commonly used cotton miticide in the Plains is abamectin, which costs about $6 to $7 per acre (MRD, 2011-2015). If needed, the cost of this additional miticide application would more than double the impacts estimated in Table 16.

West Alternatives and Impacts

Table 17 presents information on the insecticides used to target aphids and plant bugs, the two primary targets of neonicotinoid usage in the West cotton production area. Aphids are not considered a primary pest of cotton; however, some regions may experience aphid pest problems during the early season (UC ANR, 2015). Flonicamid, alone or in combination with another insecticide, is the primary chemical used to control both aphids and plant bugs and is the most likely alternative growers would use in the absence of neonicotinoids (MRD 2010-2014; UC ANR, 2015). Acetamiprid is also recommended for aphid control in the West (UC ANR, 2015). It is somewhat more expensive than flonicamid and would not also control plant bugs if the pests occurred together. For aphid control, this implies that, for growers currently using neonicotinoids, there may be increases in insecticide cost of \$3-\$4/acre, with the use of flonicamid, to \$7-\$8/acre with the use of acetamiprid (Table 17). For control of plant bugs, insecticide costs could increase \$2-\$7/acre depending on whether growers are currently using clothianidin or imidacloprid (Table 17).

Table 17. Insecticides Used for Neonicotinoid Target Pests, Square to Harvest, West

Pest	Area Treated Annually	Active Ingredient	% Total Acres Treated [1]	Average $/acre
Aphids	251,000	Flonicamid [2]	19	\$9.90
		Acetamiprid [2]	16	\$13.00
		Chlorpyrifos	13	\$8.50
		Naled	12	\$11.50
		Clothianidin	9	\$6.70
		Imidacloprid	9	\$5.80
		Flonicamid + Abamectin	7	\$21.90
Plant Bugs	537,000	Flonicamid [3]	22	\$10.40
		Oxamyl	11	\$15.90
		Clothianidin	10	\$8.30
		Imidacloprid	7	\$3.50
		Flonicamid + Other	7	\$21.20

Source: MRD (2010-2014)

1 Percent of acres treated, rate, and cost includes tank mixes with other products, unless otherwise noted. Due to mixtures, sum of percentages may exceed 100.

2 Excluding mixtures of flonicamid and acetamiprid.

3 Stand-alone product.

Estimated impacts on cotton growers in the West, if EPA were to prohibit use of neonicotinoids from pinhead squaring through harvest, are shown in Table 18. BEAD estimates nearly \$600,000 in annual increased insecticide cost. On average, about 107,000 acres of cotton are treated with neonicotinoids during the pinhead squaring to harvest stages, with some acres receiving multiple treatments (Table 7). The average impact on a treated acre is, therefore, around \$5.60/acre per year, ranging from \$2-\$8/acre with potential impacts of nearly \$15/acre if growers would normally apply neonicotinoids for multiple pest outbreaks.

Table 18. Impacts of Neonicotinoid Restrictions, Square to Harvest, West

	Baseline	Aphid	Plant Bug
Gross Revenue ($/acre)	1,995	1,995	1,995
Operating Costs ($/acre)			
Pesticides [1]	244	247-252	246-251
Other Costs	967	967	967
Net Operating Revenue ($/acre)	784	776-781	777-782
Loss as Percent of Net		0.4-1.0%	0.3-0.9%
Total Acres Affected	126,000	30,100	95,900
Total Annual Cost	$597,000	$166,000	$432,000

Source: See Tables 1 and 2. Additional pesticide cost from Table 16.

1 Baseline pesticide costs include use of neonicotinoid; additional costs are based on the use of acetamiprid of flonicamid for aphid control and flonicamid for plant bug control.

BEAD assumes the average cost per acre, over all the affected acres, is represented by the mid-point in the ranges of additional insecticide cost. If all growers can use the least expensive alternatives, regional impacts could be about $192,000 annually. However, if all growers incur additional insecticide costs at the high end of the ranges, regional impacts would be $912,000 per year. Expected impacts are about $597,000 per year, which is about $4.70 per treated acre, on average, or about 0.6 percent of net operating revenue. About 20,000 acres of cotton are treated twice between the pre-bloom and bloom periods; impacts to an acre treated twice is estimated to average about $9.50 or 1.2 percent of net operating revenue. Regional costs can be apportioned between the pre-bloom and bloom periods. Total acres treated between pinhead squaring and the beginning of bloom averages about 81,200 (Table 7), implying impacts of about $385,000 per year. On average, there are about 44,500 total acres treated with neonicotinoids through bloom to harvest. Estimated annual average impacts of a restriction against applications only during bloom are about $211,000.

An aerial restriction would affect about 56,000 acres at an expected cost of $265,000 per year while a 30 percent reduction in maximum label rates would affect about 49,300 acres per year and is estimated to cost about $234,000 annually.

CONCLUSION

BEAD estimates that the annual value of neonicotinoid use during the periods from pinhead squaring through harvest to be about $6.9 million per year, nationally (Table 19). If EPA were to restrict usage during this period to reduce exposure to pollinators, about 1.2 million acres of cotton, or about 13 percent of the U.S. cotton acreage, would be affected. While a large proportion of acreage would be affected, the estimated impacts are small in proportion to the total value of cotton production in the United States, approximately 0.1 percent. Moreover, it is unlikely that yields would be affected, since alternatives would provide similar levels of control. Therefore, BEAD concludes that there will not be impacts to the broader economy in terms of increased prices to processors or consumers; however, growers would bear the full impacts of

ED_006569M_00137204-00028

increases in the cost of production. The greatest impacts would be felt in the Mid-South production region. About 60 percent of the affected acreage is in the Mid-South and the per-acre costs are the highest across the regions. Almost 40 percent of the total acres of cotton grown in the region would be affected.

On average across all affected acres, BEAD estimates the cost of switching from neonicotinoid insecticides to an alternative during this period of cotton production to be about $5.70 per acre (Table 19). For growers relying on neonicotinoid insecticides, this amounts to about 2.3 percent of the net operating revenue derived from cotton production. Average costs range from about $2.80 per acre in the Southeast to $7.10 per acre in the Mid-South where many treated acres are located. There is, of course, some variability around the average; some growers would be impacted less but other growers benefit more from the use of neonicotinoids, for example those who make multiple applications for season-long pest control. It is also important to note that net operating revenue does not account for fixed costs of production and that cotton production may not be a producer's sole source of revenue.

Table 19. Annual Impacts of Neonicotinoid Restrictions, Square to Harvest

Region	Affected Acres	Estimated Impact	Average Cost per Acre	Impact (percent of net operating revenue [1])
Southeast	234,000	$649,000	$2.80	1.5%
Mid-South	707,000	$5,044,000	$7.10	2.6%
Plains	152,000	$606,000	$4.00	1.9%
West	107,000	$597,000	$5.60	0.7%
U.S.	1,200,000	$6,896,000	$5.70	2.3%

Source: MRD (2010-2014); Tables 11, 13, 15, 17. Figures may not sum due to rounding.
[1] For U.S., acre-weighted average net operating revenue is $249/acre.

Table 20 allocates the impacts over the pre-bloom and bloom periods, given total acres treated in each period. Most neonicotinoid applications are made in the pre-bloom period, defined as the point from pinhead squaring to the beginning of bloom; hence the majority of the impacts are concentrated in this period, which lasts about three weeks. Impacts of a pre-bloom restriction only are estimated to average about $5.2 million per year. Fewer acres are treated while cotton is in bloom. Impacts from a bloom time restriction, which lasts 10 to 14 weeks, are estimated to average over $1.7 million per year.

Table 20. Annual Impacts of Neonicotinoid Restrictions, Pre-Bloom and Bloom

Region	Pre-Bloom Impact	Bloom Impact	Total Impact
Southeast	$473,000	$175,000	$649,000
Mid-South	$3,872,000	$1,172,000	$5,044,000
Plains	$446,000	$161,000	$606,000
West	$385,000	$211,000	$597,000
U.S.	$5,176,000	$1,719,000	$6,896,000

Source: Tables 7, 19. Figures may not sum due to rounding.

ED_006569M_00137204-00029

This analysis also considered the costs of other potential strategies to reduce pollinator exposure to neonicotinoid residues, summarized in Table 21. A restriction on aerial applications can reduce exposure to off-site areas where pollinators may forage. Per-acre impacts of such a restriction are expected to be similar to that of the broader prohibition, but would affect fewer acres. On average, 159,000 acres of cotton are treated with neonicotinoids by air; expected cost is estimated to average about $659,000 per year nationally. The Mid-South and West regions would bear most of the impacts. A reduction in the label rates would leave less residues, at least on acres treated near the maximum allowed. For example, a 30 percent reduction in the label rates for the neonicotinoids would affect approximately 624,000 acres at an expected cost of $2.3 million annually. Most of the affected acreage would be in the Mid-South.

Table 21. Annual Impacts of other Potential Risk Mitigation

Region	Aerial Prohibition		30% Rate Reduction	
	Acres	$	Acres	$
Southeast	negligible		33,600	$79,000
Mid-South	98,800	$383,000	483,000	$1,873,000
Plains	4,000	$10,700	58,500	$158,000
West	56,000	$265,000	49,300	$234,000
U.S.	159,000	$659,000	624,000	$2,342,000

Source: Tables 8, 9, 19. Figures may not sum due to rounding.

Impacts arise due to growers using alternative chemistries. BEAD anticipates most growers currently relying on neonicotinoids would switch to organophosphate and/or synthetic pyrethroid insecticides if neonicotinoids were not available for use in the pre-bloom and bloom periods. The estimated impacts assume the continued availability and efficacy of these chemistries. Increased reliance on synthetic pyrethroids may exacerbate resistance problems, for example, particularly for control of plant bugs.

This analysis does not account for the potential for other pest problems to arise; for example, use of alternatives such as acephate and synthetic pyrethroids have been known to cause secondary pest outbreaks, particularly mites. If an additional mite treatment were needed, the per-acre costs could double or more, depending on the region and the miticide of choice. As with other impacts, mite outbreaks are most likely to be an issue in the Mid-South. Neonicotinoids may also be valuable for control of other currently minor pests, for which resistance management is a concern, for example Silverleaf whiteflies in the Southeast. Given these factors, the impacts shown in Table 19 may be underestimated.

REFERENCES

Emfinger, K., B. R. Leonard, J. Gore, and D. Cook. 2001. Insecticide toxicity to southern green, *Nezara viridula*(L.), and brown, *Euschistus servus* (Say), stink bugs, pp.1159D1161. *In* P. Dugger and D. A Richter [eds.], Proceedings of the Beltwide Cotton Conferences. National Cotton Council, Memphis, TN.

ED_006569M_00137204-00030

EPA. 2017a. Draft Assessment of the Potential Effects of Dinotefuran to Bees. F. Farruggia and R. Bohaty, risk assessors. Environmental Fate and Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency. January 3, 139 p. Available at http://www.regulations.gov, docket EPA-HQ-OPP-2011-0920, document 0014.

EPA. 2017b. Preliminary Bee Risk Assessment to Support the Registration Review of Clothianidin and Thiamethoxam. K. Garber, R. Mroz, C. Koper, M. Wagman, A. Blankinship, W. Eckel, risk assessors. Environmental Fate and Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency. January 5, 414 p. Available at http://www.regulations.gov, dockets EPA-HQ-OPP-2011-0865 (clothianidin), document 0173 and EPA-HQ-OPP-2011-0581 (thiamethoxam), document 0034).

EPA. 2017c. Registration Review Update on the Four Neonicotinoid Insecticides. N. Anderson, and K. Sherman, Branch Chiefs. Pesticide Re-Evaluation Division, Office of Pesticide Programs, U.S. Environmental Protection Agency. January 12, 9 p. Available at http://www.regulations.gov, dockets EPA-HQ-OPP-2008-0844 (imidacloprid), document 1089; EPA-HQ-OPP-2011-0865 (clothianidin), document 0175; EPA-HQ-OPP-0920 (dinotefuran), document 0016), and EPA-HQ-OPP-2011-0581 (thiamethoxam), document 0036).

EPA. 2016. Preliminary Pollinator Assessment to Support the Registration Review of Imidacloprid. J. Housenger, K. Sappington, and M. Ruhman, risk assessors. Environmental Fate and Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency. January 4, 305 p. Available at http://www.regulations.gov, docket EPA-HQ-OPP-2008-0844, document 0139.

EPA, PMRA, CDPR. 2014. Guidance for Assessing Pesticide Risks to Bees. Office of Pesticide Programs, U.S. Environmental Protection Agency; Heath Canada Pest Management Regulatory Agency; and California Department of Pesticide Regulation. June 19. 59 pp. Available at https://www.epa.gov/pollinator-protection/pollinator-risk-assessment-guidance

Gore, J., and Cachot, A. 2017. Mississippi State University Cotton Extension Experts, personal communication to BEAD via the National Cotton Council forum, Memphis, Tennessee, June 15-16, 2017.

Hutmacher, R. S. Wright, L. Godfrey, D. Munk, B. Marsh, K. Klonskey, R. DeMoura, and K. Tumber. 2012. Sample Costs to Produce Cotton, Pima Variety, San Joaquin Valley. University of California Cooperative Extension. Available at https://coststudyfiles.ucdavis.edu/uploads/cs_public/a3/60/a360464e-9d4c-4948-ac28-82978d9e4be7/cotton2012pima.pdf.

Jenkins, P. 2016. Net Loss: Economic Efficacy and Costs of Neonicotinoid Insecticides used as Seed Coatings: Updates from the United States and Europe. Center for Food Safety, December. Available at http://www.centerforfoodsafety.org/files/efficacy-netloss12616_38208.pdf.

Kerns, D. 2017. Texas A&M University Cotton Extension Expert, personal communication to BEAD via the National Cotton Council forum, Memphis, Tennessee, June 15-16, 2017.

Knight, I., G. Rains, A. Culbreath, and M. Toews. Conservation tillage and thiamethoxam seed treatments as tools to reduce thrips densities and disease in cotton and peanut. Crop Protection, vol 76, pp. 92-99, October.

Market Research Data (MRD). 2010-2014. Data collected and sold by a private market research firm. Data collected on pesticide use for about 60 crops by annual surveys of agricultural users in the continental United States. Survey methodology provides statistically valid results, typically at the state level.

Mississippi State University. 2011-2015. Cotton Insect Losses. Available at http://www.entomology.msstate.edu/resources/croplosses. Accessed Nov, 2016.

Mitchell, P., and F. Dong. 2015. An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in the United States and Canada. AgInfomatics, LLC. Available at http://aginfomatics.com/uploads/3/4/2/2/34223974/economic_assessment_benefits_neonicotinoid.pdf.

NCC. Undated. Growth and Development of a Cotton Plant. Advancing Cotton Education. National Cotton Council and the Cotton Foundation. Available at http://www.cotton.org/tech/ace/growth-and-development.cfm.

Reed, T., and Smith, R. 2017. Auburn University Cotton Extension Experts, personal communication to BEAD via the National Cotton Council forum, Memphis, Tennessee, June 15-16, 2017.

Reisig, D.D., and L.D. Godfrey. 2010. Remotely sensing arthropod and nutrient stressed plants: a case study with nitrogen and cotton aphid (hemipteran: aphididae). Pest Management, 39.

Roberts, P. 2017. University of Georgia Cotton Extension Expert, personal communication to BEAD via the National Cotton Council forum, Memphis, Tennessee, June 15-16, 2017..

Snodgrass, G., Adamczyk, J., Gore, J. 2005. Toxicity of insecticides in glass-vial bioassay to adult brown, green, and southern green stink bugs (Heteroptera: Pentatomidae). J. Econ. Entomol. (98): 177D181

Stevenson, D., and M. Matocha. 2005. A Pest Management Strategic Plan for Cotton Production in Texas. Texas Cooperative Extension, Texas A&M University System. Available at https://ipmdata.ipmcenters.org/documents/pmsps/TXCotton.pdf.

ED_006569M_00137204-00032

Stewart, S. 2017. University of Tennessee Cotton Extension Expert, Personal communication to BEAD via tha National Cotton Council forum, Memphis, Tennessee, June 15-16.

Tabshnik, B., T. Brévault, and Y. Carrière. 2013. Insect resistance to Bt Crops: Lessons from the first billion acres. Nature Biotechnology, 31: 510-521. June. Available at http://www.nature.com/nbt/journal/v31/n6/abs/nbt.2597.html.

UC ANR. 2015. UC IPM Pest Management Guidelines: Cotton. Agricultural and Natural Resources, University of California. UC ANR Publication 344, revised January 19, 2017. Available at http://ipm.ucanr.edu/PDF/PMG/pmgcotton.pdf.

UGA. 2016. Georgia Cotton Production Guide. Cooperative Extension, College of Agriculture and Environmental Sciences, The University of Georgia. Available at http://www.ugacotton.com/vault/file/2016-UGA-Cotton-Production-Guide.pdf.

USDA/ERS. 2016a. Commodity Cost and Returns, Cotton. Economic Research Service, US Department of Agriculture. Available at https://www.ers.usda.gov/data-products/commodity-costs-and-returns/. Accessed Feb, 2017.

USDA/ERS. 2016b. Recent Trends in GE Adoption. Available at https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx.

USDA/NASS. 2016. Crop Production/Crop Values. National Agricultural Statistics Service, US Department of Agriculture. Available at https://quickstats.nass.usda.gov/. Accessed Feb, 2017.

UT. 2016. Insect Control Recommendations for Field Crops. UT Extension, Institute of Agriculture, The University of Tennessee. Publication Bulletin 1768. Available at https://extension.tennessee.edu/publications/Documents/pb1768.pdf.

Willrich, M., Leonard, B., Cook, D. 2003. Laboratory and field evaluations of insecticide toxicity to stink bugs (Heteroptera: Pentatomidae). Journal of Cotton Science (7) 156-163.

Wrona, A., J. Banks, K. Hake, K. Lege, M. Patterson, B. Roberts, C. Snipes, and J. Supak. 1996. Achieving a Clean Finish. Cotton Physiology Today (7): 25-32. Available at https://www.cotton.org/tech/physiology/cpt/defoliation/upload/CPT-Aug96-REPOP.pdf.

ED_006569M_00137204-00033